## REMARKS

### Present Status of the Application

The Office Action rejected Claims 1-7 and 9-17 under 35 U.S.C. 112 as being indefinite for failing to particularly point out and distinctly claim the subject matter which Applicant regards as the invention.

The Office Action rejected Claims 1-17 and 9-17 under 35 U.S.C. 102(b) as anticipated by or, in the alternative under 35 U.S.C. 103(a) as obvious over Demuchuk A V et al (Reference 1 herein after).

The Office Action rejected Claims 1-17 and 9-17 under 35 U.S.C. 102(b) as anticipated by or, in the alternative under 35 U.S.C. 103(a) as obvious over P. Milani et al (Reference 2 herein after).

The Office Action rejected Claims 1-17 and 9-17 under 35 U.S.C. 102(b) as anticipated by or, in the alternative under 35 U.S.C. 103(a) as obvious over JP59165428A (Reference 3 herein after).

The Office Action rejected Claims 1-17 and 9-17 under 35 U.S.C. 102(b) as anticipated by or, in the alternative under 35 U.S.C. 103(a) as obvious over WO0216149A (Reference 4 herein after).

The Office Action rejected Claims 1-17 and 9-17 under 35 U.S.C. 102(b) as anticipated by or, in the alternative under 35 U.S.C. 103(a) as obvious over US5417896 (Reference 5 herein after).

The Office Action rejected Claims 1-17 and 9-17 under 35 U.S.C. 102(b) as anticipated by or, in the alternative under 35 U.S.C. 103(a) as obvious over US5072091 (Reference 6 herein after).

The Office Action rejected Claims 1-17 and 9-17 under 35 U.S.C. 102(b) as anticipated by or, in the alternative under 35 U.S.C. 103(a) as obvious over M. Bolle et al (Reference 7 herein after).

The Office Action rejected Claims 1-17 and 9-17 under 35 U.S.C. 102(b) as anticipated by or, in the alternative under 35 U.S.C. 103(a) as obvious over JP04091875A (Reference 8 herein after).

The Office Action rejected Claims 3 and 4 under 35 U.S.C. 103(a) as being unpatentable over the references applied above and further in view of JP59168403A (Reference 9 herein after).

Applicants respectfully traverse the rejections addressed to claims 1-7 and claims 9-17 for at least the reasons set forth below.

**Discussion of the Claim rejections under 35 U.S.C. 112:**

**1. Regarding Claim Amendments:**

Applicant has inserted the limitation of "femtosecond laser" into **claim 1**. The amendments relating to "femtosecond laser" are supported by the paragraphs [0048] to [0049] of the specification of the present invention. The related paragraphs are listed as follows:

> [0048] In the case of irradiating an ultra-short pulse laser (femtosecond laser) beam to a material surface as the first aspect of the present invention, the material is protected from thermal degradation of its properties owing to the extremely small pulse width of the laser, because heat conduction barely takes place and hence a substrate temperature close to the irradiation point barely increases, unlike the case of irradiating a picosecond or nanosecond pulse laser of a CO.sub.2 laser or YAG laser. In addition, since a minute periodic structure can be formed only at a point where the laser beam has been irradiated, this method is quite suitable for processing small parts such as those for a micromachine. [0049] More specifically, a thermal diffusion length L.sub.D of the laser beam irradiation can be defined as L.sub.D=(D.tau..sub.1).sup.1/2, where D represents a thermal diffusion coefficient of the material, and .tau..sub.1 a pulse width of the laser. Here, the thermal diffusion coefficient is defined as D=k.sub.T/.rho.c.sub.p, where k.sub.T, .tau., and c.sub.p are thermal conductivity, density, and specific heat, respectively. Accordingly, since the thermal diffusion length L.sub.D is proportional to the square root of the pulse width .tau..sub.1, irradiating an ultra-short pulse laser beam makes the thermal diffusion length very short, and when the pulse width is shorter than a picosecond level, the thermal diffusion is reduced to a practically negligible level, which is advantageous for processing small parts.

In addition, Applicant has inserted "in which the laser beam is scanned on the material surface with a laser scanning speed being set such that the number of pulses of the laser beam irradiated on an identical position of the material surface is within a range of 10 to 300" so as to clarify "overlapped scanning" in **Claim 1**. The amendments are supported by original Claim 2 and the paragraphs [0050] and [0051] of the specification of the present invention. The related paragraphs are listed as follows:

> [0050] When the laser beam is irradiated on the substrate surface, the laser beam is scattered by bumps and dips on the substrate, which is defined as a surface scattering. When a linear-polarized laser beam is irradiated on the substrate, an interference takes place between the p-polarization component of the incident beam 1 and the surface scattered wave along the substrate surface. When the fluence of the incident beam is near the ablation threshold, the ablation takes place only at a region of the interference between the incident beam and the surface scattered wave along the substrate surface. Once the ablation starts and thereby a surface roughness increases, an intensity of the surface scattering becomes greater at the next irradiation of the laser beam, by which the ablation progresses and the interference also occurs at a region one wavelength .lamda. farther. By repeating the laser beam irradiation, a periodic structure (grating structure) is spontaneously formed, at an interval equal to one wavelength. In this way, irradiation of a uniaxial laser beam can form a periodic structure. Accordingly, the apparatus can be simplified, and hence can be manufactured at a lower cost. Besides, this method provides the advantages that the ripple spacing of the periodic structure is not affected by a vibration of the table, and that the processing can be performed over a broader range of working distance in the direction of the optical axis, such that the periodic structure can also be formed on a curved surface.

> [0051] The ripples of the periodic structure spontaneously and sequentially formed at a wavelength interval by repetition of the laser beam irradiation, as the second aspect of the present invention, grow to the order of the wavelength by scores of shots, but irradiation of more than 300 shots incurs an excessive thermal effect, thus to make the structure vague. Accordingly, performing the overlapped scanning with 10 to 300 shots of laser beam irradiation to an identical position, allows forming the periodic structure over an extended area.

The language of "spontaneous formation" has been expressed in other way in **Claim 1** to make Claim 1 more clear. **Claim 1** has been amended to further define the irradiation of the laser beam on the material surface and the formation of the periodic structure on the material surface, which would imply "spontaneous formation".

The language of "grating structure" of claim 7 means the same structure as "periodic structure" in claim 1. So Applicant has deleted claim 7.

The amendments of **Claim 10** are supported by the paragraph [0063] of the specification of the present invention. The related paragraph is listed as follows:

> [0063] The tenth aspect of the present invention is also based on the fact that changing a direction of polarization of the laser beam allows changing a direction of the grating structure. In the case where, after once forming a continuous or spaced grating structure in one direction by irradiating a laser beam near an ablation threshold and executing an overlapped scanning on the irradiated region in one direction, a relative angle between the material surface and the direction of polarization of the laser beam is changed, followed by irradiation of the laser beam near the ablation threshold on a region adjacent to or spaced from the grating structure already formed and overlapped scanning on the newly irradiated region, a different grating structure can be formed in the region adjacent to or

spaced from the first formed grating structure. Accordingly, changing the relative angle between the material surface and the direction of polarization of the laser beam by 90 degrees, when forming the latter grating structure, results in formation of a grating structure in an X direction and the other in a Y direction, disposed in a mixed layout, and changing the relative angle between the material surface and the direction of polarization of the laser beam by a desired angle other than 90 degrees leads to formation of the grating structures oriented in different directions and disposed in a mixed layout.

The amendments of **Claim 11** are supported by the paragraph [0064] of the specification of the present invention. The related paragraph is listed as follows:

[0064] According to the eleventh aspect of the present invention, a laser beam emitted by a laser generator is split into two laser beams with a half mirror, thus to produce an optical delay in one of the beams. The both beams are subjected to a polarizer for polarization in a predetermined direction, and transmitted to another half mirror, which merges the two beams polarized in the predetermined direction, so that both beams are irradiated on a material surface. In this way, a laser beam near an ablation threshold having a plurality of pulses and including beams of a different direction of polarization can be irradiated on the material surface, at a predetermined time interval. Then, the overlapped scanning on the irradiated region results in spontaneous and simultaneous formation of a grating structure overlapped in different directions. Accordingly, for example, irradiating a laser beam near an ablation threshold having a plurality of pulses and directions of polarization that are different by 90 degrees at a predetermined time interval, and executing an overlapped scanning over the irradiated region, results in spontaneous and simultaneous formation of a check patterned grating structure overlapped in an X direction and in Y direction which is orthogonal to the X direction. Also, irradiating laser beams near an ablation threshold having a plurality of pulses and directions of polarization that are different by a desired angle other than 90 degrees at a predetermined time interval, and

executing an overlapped scanning over the irradiated region, results in spontaneous and simultaneous formation of a bias check patterned grating structure intersecting in the desired angle other than 90 degrees.

**2. Response to Claim Rejections under 35 USC § 112:**

In accordance with the above amendments, Claims 1, 10 and 13 have been amended into a clear state. Claims 2 and 7 has been deleted. Therefore, the Claim Rejections under 35 USC § 112 have been overcome.

**<u>Discussion of Claim rejections under 35 U.S.C. 103 (a):</u>**

**3. Regarding Claims 1-7 and 9-17:**

In accordance with the above amendments, Claim 1 has been amended as the following:

"1. A method of forming a periodic structure, comprising:

irradiating a surface of a material with a linearly polarized single laser beam <u>of a femtosecond laser</u>, of which a fluence is above but nearly as low as ablation threshold; and executing an overlapped scanning <u>in which the laser beam is scanned on the material surface with a laser scanning speed being set such that the number of pulses of the laser beam irradiated on an identical position of the material surface is within a range of 10 to 300,</u> so as to cause the ablation at a section where interference has taken place between a p-polarization component of an incident beam and a <u>p-polarization component of a</u> surface scattered wave generated along the material surface, and to thereby <u>form</u> a periodic structure<u> on the material surface, wherein the periodic structure has </u>ripple<u>s</u> spacing near a wavelength of the incident beam in a direction perpendicular to a polarization direction of the incident beam.".

It is noted that, "femtosecond laser" is superior in coherence, so that interference between the p-polarization component of the incident beam and the p-polarization component of the surface scattered wave is effectively taken place.

One pulse (one shot) of the laser beam having a fluence just above the ablation threshold is able to cause only a slight ablation on the material surface. The overlapped scanning defined in claim 1 is able to secure the necessary ablation of the material surface to form the periodic structure having the necessary depth.

In addition, the surface scattered waves scatted from an identical position (point) on which the plurality of pulses of the laser beam are irradiated have a common origin point of scattering, so that the ripples of the periodic structure are well arranged on the material surface.

Further, the overlapped scanning is able to form well arranged ripples (periodic structure) simply and extensively on the material surface.

The language of "spontaneous formation" in Claim 1 has been expressed in a another clear way to clarify the limitations of Claim 1. The amended Claim 1 shows that the periodic structure is formed by self-organization of the material, different from Reference 2 (fullerite film), Reference 4 (nickel-phosphorus alloy deposit) and so on where a coating layer such as fullerite film and nickel-phosphorus alloy deposit is formed of the material surface, and the coating layer on the material surface is irradiates with laser beam to form a periodic structure.

**Reference 1 (Demchuk A. V. et al.)** discloses the method for forming a periodic structure wherein localized melting of the surface layer of the material occurs in the central

region of the area of the laser spot, and then the local melt region in the central region expand due to surface vibrations to form a periodic structure (see the last paragraph of the left column of page 494 and lines 10-14 of the second paragraph of the right column of the next page). Namely the method of Reference 1 is depending on localized melting of the surface layer of the material and vibration of the local melt region to form a periodic structure, **which dose not** cause the ablation of the material and the interference between the incident beam and the surface scattered wave. In other words, the principle of formation of a periodic structure is **quite different** between Reference 1 and the present invention. Thus Reference 1 **fails** to disclose such the features in Claim 1 as **"femtosecond laser"**, **"overlapped scanning"**, **and "the ablation at a section where interference has taken place between a p-polarization component of an incident beam and a p-polarization component of a surface scattered wave"**. **Claim 1 is novel and patentable over Reference 1.**

**In Reference 2 (P. Milani et al.)**, polycrystalline fullerite films are deposited on the material substrates. Fig. 1(a) of Reference 2 shows the surface of the polycrystalline fullerite film deposited on the material substrate. Figs. 1(b) and 1(c) show the patterns on the external circular regions of the area of the laser spot obtained after irradiation. Namely, Reference 2 discloses only the periodic structure on the external circular regions of the area of the laser spot, therefore **fails** to disclose the feature of **"overlapped scanning"** in Claim 1 which enable to extensively form a periodic structure on the material surface. In addition, in Reference 2 the polycrystalline fullerite film deposited on the material surface is irradiated with the laser beam

to form a periodic structure. Therefore Reference 2 **fails** to disclose the feature of **"the ablation of the material surface at a section where interference has taken place between a p-polarization component of an incident beam and a p-polarization component of a surface scattered wave, and to thereby form a periodic structure on the material surface"** in Claim 1. Furthermore, Reference 2 **fails** to disclose the features of **"femtosecond laser"** in Claim 1. **Claim 1 is novel and patentable over Reference 2.**

**In Reference 3 (JP59-165428A)**, the semiconductor base plate is immersed into the photo chemical etchant and then irradiated with a linearly polarized single laser light. The diffraction pattern of the laser light formed on the semiconductor base plate is to accelerate etching effect by the photo chemical etchant. Namely Reference 3 discloses etching technique of the semiconductor base plate, which is **quite different** in the principle of formation of a periodic structure from the present invention. In addition Reference 3 **fails** to disclose **"femtosecond laser"** and **"overlapped scanning"** in Claim 1. **Claim 1 is novel and patentable over Reference 3.**

**In Reference 4 (WO02/16149A1),** a nickel-phosphorus alloy deposit 3 is formed on the surface of the aluminum substrate 2. Then the aluminum substrate 2 is subjected to heat-treatment to form the oxide film 3a on the surface layer of the nickel-phosphorus alloy deposit 3. The oxide film 3a serves as a waveguide of the irradiated laser beam. Thus Reference 4 disclose the similar technique as discloses in JP06-212451 and JP06-198466 about which

Applicant have argued in detail in the response filed on August 27, 2009. Reference 4 **fails** to discloses **"femtosecond laser", "overlapped scanning", "cause the ablation on the material surface at a section where interference has taken place between a p-polarization component of an incident beam and a p-polarization component of a surface scattered wave generated along the material surface, and to thereby form a periodic structure on the material surface"** in Claim 1. **Claim 1 is novel and patentable over Reference 4.**

**Reference 5 (US5417896)** discloses the method for production of slight surface roughness of a sheet without removing any material from the sheet by linearly polarized UV radiation of which the energy density is below the ablation threshold (see claim 1, lines 6-9 of column 3, lines 18-25 of column 4). Reference 5 **fails** to disclose **"femtosecond laser", "fluence is above but nearly as low as ablation threshold", "overlapped scanning" and "cause the ablation on the material surface at a section where interference has taken place between a p-polarization component of an incident beam and a p-polarization component of a surface scattered wave generated along the material surface"** in Claim 1 of the present invention. **Claim 1 is novel and patentable over Reference 5.**

**Reference 6 (US5072091)** discloses the method for forming the fine irregularity patterns on the metal surface by utilizing the interfering light of a laser beam produced by the mutual overlapping of bright pattern components in a laser beam of multi-mode, or by the overlapping of two or more beams into which a single laser beam is split, or by the overlapping

of an original beam component and the laterally displaced beam component (see claims 1-4). The method of Reference 6 is **difficult** in adjusting optical system. Reference 6 **fails** to disclose **"irradiating a surface of a material with a linearly polarized single laser beam", "femtosecond laser", "overlapped scanning" and "the ablation on the material surface at a section where interference has taken place between a p-polarization component of an incident beam and a p-polarization component of a surface scattered wave generated along the material surface"** in Claim 1 of the present invention. **Claim 1 is novel and patentable over Reference 6.**

**Reference 7** **(M. Bolle et al.)** teaches that fluence is below the ablation threshold and must be chosen in a narrow window which depends on the polymer and the wavelength (see the abstract on the upper portion on page 674). **Please note** such descriptions that "This is well below the threshold for ablation…and means that the pattern is not produced by ablation,…. In our previous work, ablation of the same material produced only a large and rather random surface roughness" (lines 15-21 of right column of page 674). Reference 7 **fails** to disclose, **"femtosecond laser", "fluence is above but nearly as low as ablation threshold", "overlapped scanning" and "the ablation on the material surface at a section where interference has taken place between a p-polarization component of an incident beam and a p-polarization component of a surface scattered wave generated along the material surface"** in Claim 1 of the present invention. **Claim 1 is novel and patentable over Reference 7.**

**Reference 8 (JP04-91875A)** discloses the similar method to Reference 6 for forming the fine ruggedness on the metal surface by utilizing the interference beam M of a laser produced by the mutual overlapping of bright pattern components in a laser beam of multi-mode, or by the overlapping of two or more beams into which a single laser beam is split, or by the overlapping of an original beam component and the laterally displaced beam component. The method of Reference 8 is also **difficult** in adjusting optical system. Reference 8 **fails** to disclose **"irradiating a surface of a material with a linearly polarized single laser beam", "femtosecond laser", "overlapped scanning" and "the ablation on the material surface at a section where interference has taken place between a p-polarization component of an incident beam and a p-polarization component of a surface scattered wave generated along the material surface"** in Claim 1 of the present invention. **Claim 1 is novel and patentable over Reference 8.**

In accordance with the above analysis, **Claim 1 is novel and patentable over each one of the References 1-8**, therefore **dependent Claims 3-6, Claims 9-13 and Claims 15-17 are also novel and patentable over each one of the References 1-8**.

**4. Regarding Claims 3 and 4:**

The Office Action further rejected Claims 3 and 4 as being unpatentable over above References and further in view of Reference 9 (JP59168403). **Applicant respectively disagree with the following analysis.**

**In Reference 9 (JP59-168403A),** two laser lights are emitted from the end portion P and Q of the optical fibers 5 and 6 into the air as spherical surface waves to form interference fringe. Namely Reference 9 disclose the method utilizing the interference between the biaxial laser beam, which has the problems as mentioned in the present specification (see the sections [0027]-[0029] of the specification of the present invention, which is listed as follows).

> [0027] However, the method of utilizing the interference of biaxial laser beams described in the non-patented document No. 9 has the following drawbacks. According to the method it is imperative to split the laser beam to form biaxial laser beams, with additional requirements such as setting an optical path difference to be strictly identical and strictly synchronizing a laser scanning speed with a ripple spacing of the periodic structure. Accordingly, control of optical axes is extremely complicated, and the apparatus inevitably becomes complicated and expensive. Besides, the method can only be applied to a flat surface because of utilizing the interference of two optical paths in different angles, and if a table supporting the material shakes, the ripple spacing of the periodic structure becomes uneven.
>
> [0028] Likewise, the methods of forming a periodic structure described in the foregoing non-patented documents 1 through 9 are not appropriate for forming a periodic structure having an accurate ripple spacing over an extensive area through a simplified process, and therefore any practical application of those methods has not been established, since any effect thereof has not been proven yet.
>
> [0029] Accordingly, it is an object of the present invention to provide a method of forming a periodic structure utilizing a uniaxial laser beam, instead of the foregoing biaxial laser beams, on a surface of various materials. It is another object of the present invention

to provide a surface treatment technique of irradiating the laser beam on a surface of various materials, so as to change the surface characteristics thereof."

Reference 9 **fails** to disclose **"irradiating a surface of a material with a linearly polarized single laser beam", "femtosecond laser", "overlapped scanning" and "cause the ablation on the material surface at a section where interference has taken place between a p-polarization component of an incident beam and a p-polarization component of a surface scattered wave generated along the material surface"** in Claim 1 of the present invention. **Therefore, the combination of Reference 9 with each one of the above References 1-8, still cannot obtain the feature of Claim 1 of the present invention. Dependent Claims 3 and 4 are patentable over the combination of Reference 9 with each one of the above References 1-8, accordingly.**

## CONCLUSION

For at least the foregoing reasons, it is believed that all the pending claims 1, 3-6, 9-13 and claims 15-17 of the present application are patentable. If the Examiner believes that a telephone conference would expedite the examination of the above-identified patent application, the Examiner is invited to call the undersigned.

Respectfully submitted,
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